DOCUMENT RESUME

ED 121 621 SE 020 768

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TITLE Toward a Conceptual Framework and Analytical Model of the Process of Organized Technological Innovation Within the Firm.
PUB DATE Jan 76
NOTE 33p.; Contains gaps in page numbering; however, document is complete

EDRS PRICE MF-$0.83 HC-$2.06 Plus Postage
DESCRIPTORS Business; *Business Administration; *Innovation; *Literature Reviews; *Models; Research; Science Education; Scientific Research; Technological Advancement; *Technology

ABSTRACT

This paper demonstrates that the literature is sufficiently advanced to support the development of conceptual frameworks for organized technological innovation. The literature of multiyear planning and fiscal-year budgeting is examined in order to specify how corporate strategy impinges on organized technological innovation. A computer simulation model based on an interative decision mechanism is presented for use in corporate governmental policies, market considerations, and technological information. (MLH)

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TOWARD A CONCEPTUAL FRMEWORK AND ANALYTICAL MODEL OF THE PROCESS OF ORGANIZED TECHNOLOGICAL INNOVATION WITHIN THE FIRM*

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January 1975
rev. January 1976

*This state-of-art summary and resultant conceptual frmework serves as the baseline for a two-year research project funded by the office of National R&D Assessment, National Science Foundation. Drs. Baker and Sweeney are co-principal investigators.

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II BRIEF SURVEY OF THE RELEVANT INNOVATION LITERATURES

The primary purpose of this paper is to support the first of the two premises upon which our current research is based. Specifically, the purpose is to demonstrate that the literature is sufficiently advanced to support the development of conceptual frameworks in the area of organized technological innovaiton. The demonstration will be accomplished by drawing a number of working hypotheses from the literature. It is these hypotheses which become the building blocks for subsequent conceptual frameworks.

Although certain segments of the literature on organized technological innovation are summarized, no attempt is made to offer a complete survey. There are a number of surveys which review specific areas of the literature. Utterback (19) offers a review of the results of numerous studies of innovations. An excellent summary of the economics of innovation and R&D is authored by Mansfield (3,4). Zaltman, et al, (5) is a useful and recent summary of innovation in formal organizations from an organization theory viewpoint. The socio-cultural aspects of the adoption and diffusion of technological innovation are discussed by Rogers and Shoemaker (6). Finally a survey and assessment of the literature on the innovation process has recently been completed by M. Kransberg, P. Kelly, and their team members at the Georgia Institute of Technology as part of an activity funded by the National Science Foundation's Office of Nation R&D Assessment.

A. The Trend Toward Organized Innovation

The process of technological innovation in this century can be characterized by an increasingly strong trend toward the institutionalization of all its phases (7). This conclusion is not meant to imply that the importance of the individual inventor has become negligible. Such examples as Edwin Land (poloroid camera) and Chester Carlson (xerography) demonstrate that although the importance of the individual inventor may have diminished, it cannot be ignored. The conclusion is meant in the sense of Lanquish, et al, who noted that, "while it does undeniably make sense in the twentieth century to talk about the 'independent inventor' ... 'independent innovator' is almost a contradiction in terms" (7). The independent inventor is still responsible for major inventions which subsequently become innovations.

As Hughes (8) has explained, the inventor must be coupled with an entrepreneur if the invention is to develop into an innovation. In rather rare instances, e.g., Sperry and Edison, a single individual functions both as inventor and entrepreneur. Increasingly, however, the entrepreneurial role is being performed by the larger corporations who have access to the resources necessary to develop, produce, and market the innovation (7). Even when the entrepreneurial function is not initiated by one of the larger firms, the entrepreneurial function may expand to become an organization so large that the individual entrepreneur can no longer completely control it; e.g., Sperry Gyroscope Company. Another modern day counterpart of the individual entrepreneur is the so-called spin-off organization (9).

The actualization of institutionalized technological innovation was to await the general adoption of the research and development (R&D) laboratory as a vehicle for organized technological innovation. This occurred during the 1945-1955 period when a rapid growth in R&D expenditures (3) and in number of

R&D laboratories (10) was experienced. As this occurred, top corporate and R&D management searched for appropriate organizational structures and policies. In the absence of successful R&D organizational examples and of underlying R&D management theories, many firms adopted for R&D the organizational structures and policies which were being used with apparent success to manage other organizational functions; e.g., production.

The R&D activity was blended into the existing organizational hierarchy either as a new division (a "corporate laboratory") or as a new function in an existing division (a "divisional laboratory"). In many organizations the R&D activity was controlled and coordinated by mechanisms which initially had been developed to control and coordinate other organizational functions such as production. The implications of these mechanisms for organized technological innovation are still not well understood. The extent to which the potential benefit of organized technological innovation will be realized depends in large measure on how well we come to understand the informational, organizational, and social-psychological constraints on the process of organized technological innovation.

The reader should not be left with the impression that all organized technological innovation occurs in the R&D laboratory. Hollander's study (11) clearly demonstrates the importance of non-R&D innovation. Thus, the term "organized technological innovation" is intended to denote all technological innovation occurring within an organization as a result of action by one or more members of the organization. The R&D laboratory is one of the most important organizational units within which organized technological innovation is accomplished. It is not the only unit, nor can it operate independently of other organizational units (12, 13, 14).

Three working hypotheses can now be drawn:

H_1: Organized technological innovation is an increasingly important aspect of the process of technological innovation.

H_2: The R&D laboratory is an important unit of the firm in its process of technological innovation.

H_3: Organized technological innovation is a process which involves interaction among a number of organizational units.

In addition to the interaction among organizational units, the interaction of the firm with the external environment must also be considered. How data in the environment is transferred into organizational information and how various organizational mechanisms operate to focus on specific innovation activities is the topic of the next section.

B. Information Flow and Focusing Mechanisms

Each organization receives input from the external environment which it must translate into organizational goals and capabilities. Three ways in which this information transfer and translation is accomplished have been discussed in the literature:

1. Top management, with the assistance of their planning staffs, assess the external environment and determine corporate goals and policies

and thus, in a broad sense, effect a match of opportunity or need with capability. The corporate goals and policies operate as guidelines and constraints at the lower levels and it is within these guidelines and constraints that projects are proposed and evaluated (for an excellent discussion, see [1]).*

2. "Technological gatekeepers" operate as a conduit by which technological information enters the firm. These gatekeepers are often identified as the sources of the best technical ideas introduced in a laboratory and have the greater number of information contacts outside laboratory (15, 16, 17).

3. Analogous to technological gatekeepers, one author (18) has conjectured the existence of "market-need gatekeepers". He suggests that personnel in such functions as marketing, technical services, sales, etc. are sources of information regarding market needs and opportunities.

Thus, there are both formal and informal mechanisms by which external data are transferred into internal information and translated into organizational goals and capabilities.

Although the existence of market-need gatekeepers has not been verified empirically, there is widespread empirical agreement that information about market needs tends to come in some way from sources outside the firm (19). Further, there are data, gathered in a number of different firms by a number of different researchers, which indicate that from 60-90% of the ideas which resulted in technological innovations were initiated by the recognition of market needs or opportunities (19). The market information, when coupled with a technological capability, resulted in an idea for a technological innovation. The remaining ideas were initiated by recognition of a technological capability which later was coupled with a market need or opportunity. Thus, the importance of external market information to the process of organized technological innovation has been well documented.

An idea for a technological innovation is generated when a reasonably well-defined match is made of an organizational need or opportunity with a technological capability (19, 20). Thus, corporate goals and policies, and information from gatekeepers, are important informational inputs for the individual researcher and engineer. These inputs serve to focus his attention and, thus, simultaneously broaden and restrict his perceptual base.

Other important factors which operate as focusing mechanisms at the level of the individual researcher and engineer include (18, 20, 21):

1. The mind set of the individual which represents the past experiences and thought processes brought by the individual to the current activity.

2. The organizational control and coordination processes, such as selection, budgeting, scheduling, and review, which restrict individual behavior and provide secondary input regarding corporate goals and policies.

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*Note that this process provides a means of relating government policy and market structure to the internal operation of the organization.

3. The attitudes and actions of the supervisor in his roles as a) middle man in the communication of corporate goals and policies, b) a path by which organizational rewards are obtained, c) a source for critical evaluation of ideas, d) a provider of resources and administrative help, e) an implementer of control and coordination mechanisms, and f) an enforcer of rules and regulations.

4. The role of the primary groups, both social and work, as other sources of administrative, technical, and market information and of idea evaluations and as a vehicle for introducing diverse opinions regarding the range of technical options considered and the interpretation of corporate goals and policies.

In summary, the literature of organized innovation within the firm identifies a number of variables and presents empirical demonstration of their role as focusing mechanisms. However, variable interactions and their broader implications for the process of organized innovation are not well understood.

The literature summary presented above includes a number of results which should be considered in the construction of a conceptual framework, including:

H_4: An idea for a technological innovation is generated when a reasonably well-defined match is made of an organizational need or opportunity with a technological capability.

H_5: Technological gatekeepers operate as a conduit by which technological information enters the firm.

H_6: Information about market needs tends to come from sources outside the firm.

H_7: Corporate goals and policies emanate from top corporate management.

H_8: The corporate goals and policies related to technological innovation represent the organization's attempt to effect a broad match of opportunity or need with capability.

H_9: A number of focusing mechanisms operate to influence which matches of opportunity or need with technological capability are most likely to occur, including:

a) The process by which corporate goals and policies, technological capabilities, and needs or opportunities are communicated.

b) The mind set of the individuals involved in the process of organized innovation.

c) The organization's control and coordination processes.

d) The attitudes and actions of the supervisor(s).

e) The role of the primary work and social groups.

The empirical support for the hypotheses is uneven: some have considerable empirical support whereas others represent informed conjecture. Regardless,

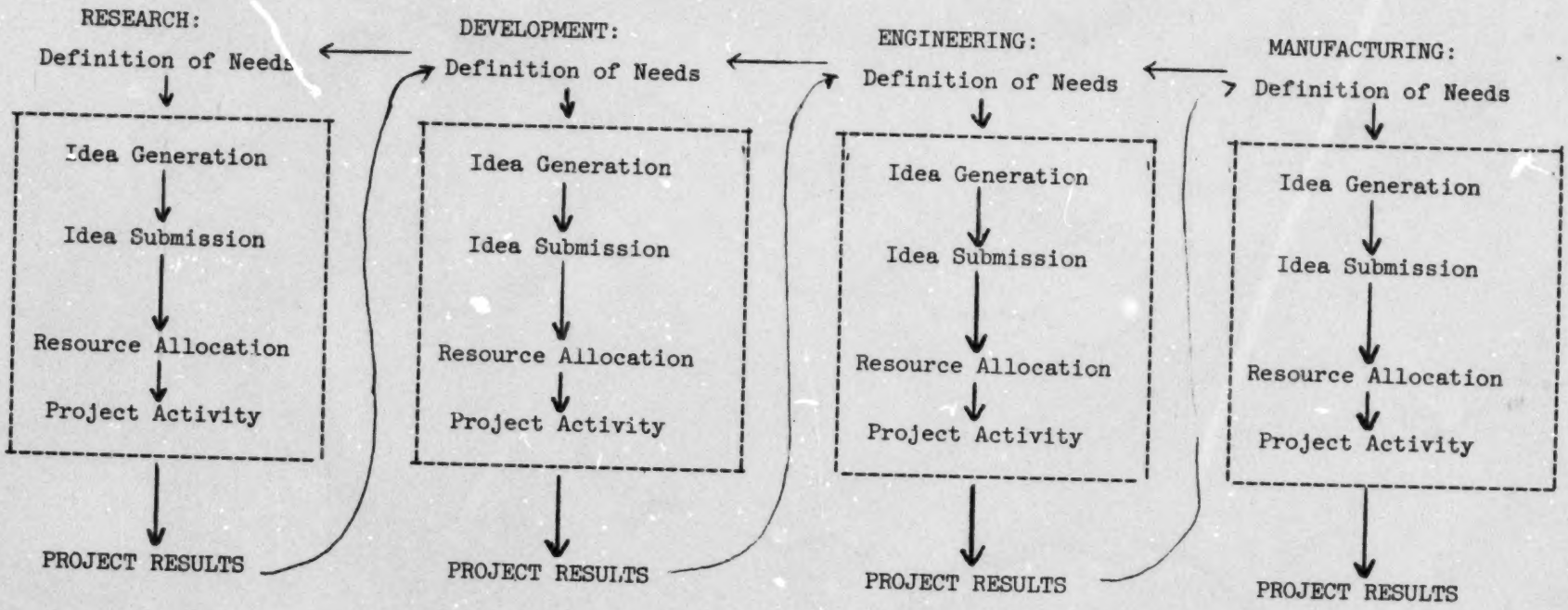
each has some literature support and,collectively, they provide a coherent, internally consistent description of how data in the environment is transferred into information within the organization and how the information and other variables serve to focus the organization on specific innovation needs or opportunities and technological capabilities.

C. Structure and Function

Because of its concentration on individual behavior and on information flow, the behavioral literature summarized in the preceding section downplays the importance of 1) the specific innovation and its inherent characteristics and 2) the mutual, self-reinforcing relationship between organizational structure and the function of technological innovation. The ecological view taken by the Georgia Tech team led to a consideration of these other factors and resulted in a working paper by Baker (2), some aspects of which are now summarized.

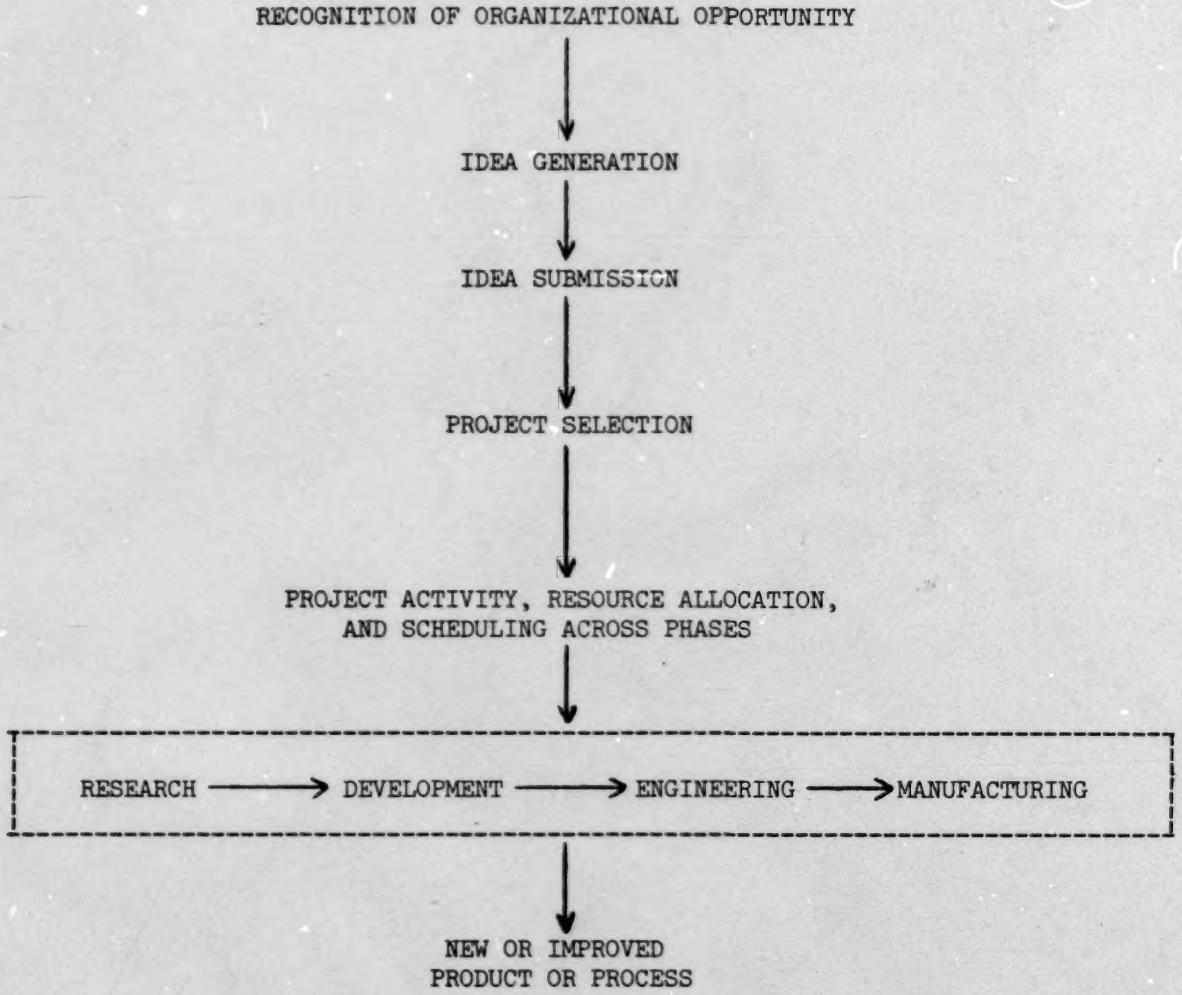
Two underlying views of organized technological innovation were proposed in the paper (2). One view suggests that the innovative activity is structured according to the phases of the innovative process. For example, the activity is subdivided according to research, development, engineering, etc. and the responsibilities are assigned accordingly. Within each process phase organizational needs are identified, ideas are generated, projects are selected, and scientists and engineers are assigned. Project selection and resource allocation take place within a process phase according to the needs of the organization for effort in each phase. The effort in one phase can be related to the organizational needs for effort in another phase. For example, if research uncovers new technological results which could be developed for use by the organization, then a transfer across phases can be accomplished by an appropriately stated need for the development phase. Similarly, development results could be transferred to engineering and engineering results to manufacturing. The flow could also be in the reverse direction; e.g., if a development activity is being stymied by inadequate technology, then a research need could be defined and communicated. In order to stress that projects are defined within each phase and that transfer occurs by communicating one phase's results or requirements to another phase, the resultant model, Figure 1, is named the "Phase-Dominant Model".

Another view suggests that the innovative activity is primarily structured according to organizational needs or opportunities; i.e., that the phases are organized around the project. Ideas are generated, projects are selected, and resources are allocated to the project - not to a process phase. A project team is responsible for accomplishing the activities necessary to complete the project and these activities most likely cut across all the process phases. As a whole, the project either progresses through the remaining phases or it is terminated. Thus, resource allocation and scheduling decisions occur within the confines of the project, but across process phases. In order to emphasize that results and requirements are not transferred from phase to phase, but that the project is viewed as requiring integrated, multiple-phase activities, the resultant model, Figure 2, is named the "Project-Dominant Model".



The boxes defined by broken lines contain activity which is conducted within each process phase.

Figure 1: Phasé-Dominant Model



The box defined by broken lines contains project activity which flows across the R&D process phases.

Figure 2: Project-Dominant Model

The two resultant models of organized technological innovation within the firm evolved from a literature synthesis. Although they have not been verified empirically, existing empirical studies yield results consistent with them (2). Further, the models provide the conceptual ability to relate structure and function in the study of organized technological innovation and hence are most relevant to the purposes of the proposal.

The preceding discussion suggests a one-way implication; namely, the view taken of the innovation process determines how the activity will be structured within the firm. The literature analysis also suggested the converse; namely, how the activity is structured determines which view of innovation will be predominate within the organization.

It is believed that during the 1945-1955 growth period for R&D, top corporate and R&D management adopted for R&D the structures and the control and coordination mechanisms which were being used with apparent success to manage other organizational functions. As a result, R&D was blended into the existing organizational hierarchy as a new division (a "corporate laboratory") or a new function in an existing division (a "divisional laboratory") and was subjected to a bureaucratic structure with hierarchical control and coordination mechanisms. In the absence of conceptual models, the implications of the hierarchical structure and the associated control and coordination mechanisms were not well understood. Specifically, it was not understood that they would most likely lead to a phase-dominant view of organized innovation.

In order to explain the significance of this implication, it is necessary to consider distinctions at the level of the specific innovation. The literature distinguishes between innovations which are concerned with incremental improvements or minor extensions, "incremental" innovations, and innovations which are concerned with new devices or with scientific or technological breakthroughs, "discontinuous" refer to how new or unique the innovation is and to how much the innovation extends current practice or existing knowledge. Other distinctions made in the literature include: size, in terms of cost and/or personnel; time to completion; level of uncertainty, both technical and economic; number of technologies; number of organizational units; number of innovation phases; urgency with which the results are needed; and extent of contribution to organizational goals and objectives (3, 4, 10, 20).

The phase-dominant orientation, and the resulting organizational structure, are consistent with the attributes of relatively small, short time horizon, single phase innovations which are carried on within one organizational unit and which involve one or a few fields of technology (for brevity, "unimodular" innovations). The phase-dominant orientation is not consistent with the attributes of relatively large, long time horizon, multiple phase innovations which cut across organizational boundaries and which involve several fields of technology ("multimodular" innovations). Conversely, the project-dominant orientation is consistent with the attributes of multimodular innovations, but inconsistent with the attributes of unimodular innovations. Table 1 is a summary comparison of the two models.

Organizational Characteristics	Phase-Dominant Model	Project-Dominant Model
Structural Focus	Projects structured around phases of the innovation process.	Phases structured around projects.
Structural Unit	Divisions within an organizational hierarchy.	Project teams which cut across organizational boundaries.
Control/Coordination	Consistent with hierarchical structure.	Inconsistent with hierarchical structure.
Information Transfer	Project needs and results across phases & organizational units.	Needs and results within the project team, but across phases.
	Eventual transfer of results to become on-going activities.	Eventual transfer of results to become on-going activities.
Project Selection	Divisional management - divisional budget.	Corporate management - risk capital.
Project Control	By phase - within each division.	By project activity - within team.
Top Management Role	Overview budget summary, yearly review.	Continual, detailed project review.
Project Characteristics		
Scope	Narrow	Broad
Technical Approaches	Inflexible	Flexible
Time Horizon	Short	Long
Number of Personnel	Few	Several
Scientific Disciplines	One, Few	Multiple
Process Phases	Single	Multiple

Summary Comparison of Phase-Dominant and Project-Dominant Models

Table 1

A conclusion is drawn, therefore, that the hierarchical structures and mechanisms adopted for R&D during the 1945-1955 period led most U.S. organizations to a phase-dominant orientation toward organized innovation. This orientation, in turn, slanted the subsequent activity toward unimodular innovations and away from multimodular innovations. When multimodular innovations were attempted they could be carried out only at high cost and with high disruption to existing organizational norms and structures.

Consider, for example, the Rubenstein and Radnor (22) finding that, even though both corporate and divisional management agreed that the emphasis of R&D should be on "multimodular" R&D programs, "unimodular" programs were much more likely to occur in the decentralized organizations which they studied. One explanation is that organizations with a phase-dominant orientation and structure are led by that very orientation and structure to identify and undertake unimodular innovations even if they would prefer to identify and undertake multimodular innovations. The current popularity of such topics as "matrix organization" and "project management" in the management practice literature can be interpreted as manifestations of a move toward project-dominant structures which will facilitate multimodular innovations. It is interesting that these suggested reorganizations can be traced to the successes demonstrated on large, federal R&D activities which were managed with a project-dominant orientation.

Two most important hypotheses can be drawn from the above literature. The hypotheses are:

H_{10}: A phase-dominant organizational structure is more conducive to unimodular innovations than to multimodular innovations.

H_{11}: A project-dominant organizational structure is more conducive to multimodular innovations than to unimodular innovations.

These hypotheses are useful in the development of conceptual frameworks for two reasons. First, they provide alternative organizational structures (project-dominant and phase-dominant) for purposes of anlaysis. Any conceptual framework should be sufficiently flexible to permit analysis of the implications of either structure for organized technological innovation. Second, they provide a first-cut verification for a conceptual framework. If analysis of the implications of a phase-dominant structure does not suggest that the organization is more conducive to unimodular innovations - or, similarly, project-dominant to multimodular - then one should seriously re-examine the framework being utilized for the analysis.

The self-reinforcing relationships connecting organizational structure and organized innovation are complex and difficult to study. No firm is likely to permit the systematic manipulation of organizational structure necessary to conduct "real-life" experimentation. Without such experimentation, the myopic, piecemeal, non-cumulative empiricism which now characterized the literature will continue. An alternative to "real-life" experimentation is simulative experimentation based on conceptual frameworks. Thus, there is a need for higher-level, integrative theories and models which can guide future empirical studies and provide a focus for cumulative results, both explanative and normative. An iterative, interactive relationship between theoretical and empirical research must evolve if a significant increase in understanding of the process of organized technological innovation is to be realized.

D. Some Theoretical Constructs

Several useful theoretical constructs appear in the organization development literature, one of the few literatures which have explicitly recognized the relationship between organizational structure and function (e.g., see 5, 24, 25, 26, 27). The literature defines such constructs as: level of complexity in the organization's incentive system (a highly complex system can reward for a large number of different behaviors); level of diversity in the task structure (a highly diverse structure permits an individual to perform a number of different tasks); degree of formalization (a highly formalized organization has highly codified tasks); and degree of centralization (the extent to which power and decision authority is in the hands of a small proportion of organizational participants).

It is our contention that these constructs are directly related to the concept of focusing mechanisms which was discussed earlier. It was noted that top management determines corporate goals and policies which operate at lower levels in the organization to focus behavior. The outward manifestations of certain administrative policies appear in terms of complexity, diversity, formalization, and centralization. By their very definition, these constructs are indicators of the extent to which individual behavior is restricted by the incentive system (complexity), by the number of tasks performed (diversity), by task definition (formalization), and by decision making freedom (centralization). Specifically, individuals in an organization which evinces high complexity, high diversity, low formalization, and low centralization should be less focused in their innovative activities than those in an organization which evinces low complexity, low diversity, high formalization, and high centralization.

Further elaboration regarding these theoretical constructs is available in the literature. For example, as a result of an in-depth study of 19 rayon and electronics firms in England and Scotland, Burns and Stalker (25) identified two types of organizations, mechanistic and organic. Table 2 is a summary description of these two types. Note that the mechanistic form can be described as hierarchical (items 4, 6) with low complexity (items 1, 2) high formalization (items 3, 8, 9), and high centralization (items 5, 7, 8); whereas, the organic form is not hierarchical (items 4, 6) and has high complexity (items 1, 2), low formalization (items 3, 8, 9), and low centralization (items 5, 7, 8). Burns and Stalker argue that there is no one best organizational form. When the environment is relatively stable and fairly certain, the mechanistic form is most appropriate; however, when the technical and market environment is changing and unstable, the organic form is most appropriate, especially for gathering and processing information.

Additional insight is provided by Zaltman, et al (5) who view innovation in terms of an initiation phase and an implementation phase. One of their hypotheses is that the organizational conditions most conducive to innovation at the initiation phase (high complexity, high diversity, low formalization, low centralization) are just opposite of those most conducive at the implementation phase (low complexity, low diversity, high formalization, high centralization). In our terminology, innovative activity should be loosely focused at the initiation phase, but tightly focused at the implementation phase.

Mechanistic	Organic
1. Tasks are broken into very specialized abstract units	1. Tasks are broken down into subunits, but relation to total task of organization is much more clear
2. Tasks remain rigidly defined	2. There is adjustment and continued redefinition of tasks through interaction of organizational members
3. Specific definition of responsibility that is attached to individual's functional role only	3. Broader acceptance of responsibility and commitment to organization that goes beyond individual's functional role
4. Strict hierarchy of control and authority	4. Less hierarchy of control and authority sanctions derive more from presumed community of interest
5. Formal leader assumed to be omniscient in knowledge concerning all matters	5. Formal leader not assumed to be omniscient in knowledge concerning all matters
6. Communication is mainly vertical between superiors and subordinates	6. Communication is lateral, between people of different ranks and resembles consultation rather than command
7. Content of communication is instructions and decisions issued by superiors	7. Content of communication is information and advice
8. Loyalty and obedience to organization and superiors is highly valued	8. Commitment to tasks and progress and expansion of the firm is highly valued
9. Importance and prestige attached to identification with organization itself	9. Importance and prestige attached to affiliations and expertise in larger environment

Table 2: Mechanistic and Organic Organizational Forms*

*From Burns and Stalker (25) and Zaltman, et al, (5)

The Burns and Stalker and the Zaltman, et al conclusions are consistent. The overall implication is that when the technical and market environment is relatively unstable and uncertain, e.g., at initiation, administrative policies should be adopted which will result in the innovative activity being loosely focused. Conversely, when the technical and market environment is relatively stable and certain, e.g., at implementation, then administrative policies should be adopted which will result in the innovative activity being tightly focused.

The following working hypotheses are supported by the organizational development literature:

H_{12}: Level of complexity in the incentive system, level of diversity in the task structure, degree of formalization of the tasks, and degree of centralization of power and decision authority are theoretical constructs which describe the extent to which administrative policies restrict individual behavior.

H_{13}: Individuals in an organization where administrative policies evince high complexity, high diversity, low formalization, and low centralization will be less focused in their innovative activity than those in an organization where administrative policies envince low complexity, low diversity, high formalization, and high centralization.

H_{14}: When the technical and market environment is relatively unstable and uncertain, administrative policies which result in the innovative activity being loosely focused are most appropriate.

H_{15}: When the technical and market environment is relatively stable and certain, then administrative policies which result in the innovative activity being tightly focused are most appropriate.

As before, these hypotheses have a dual purpose. The theoretical constructs provide a means for expressing administrative policies as focusing mechanisms and, hence, provide useful categories for analysis. In addition, the last two hypotheses, H_{14} and H_{15}, provide for a first-cut verification of a framework.

E. Summary and Discussion

The innovation literature has been surveyed and presented according to the structure which appears in the literature. A summary and partial restructuring can serve to better explain how the literature can be used as input for conceptual frameworks. Accordingly, the literature survey will be summarized in this concluding section in a manner more consistent with the needs of a conceptual framework.

Much of the surveyed literature is concerned with describing how the process of organized innovation operates. It is presented as an information process within which interaction takes place between the firm and the external environment (H_5, H_6, H_8) and, internally, among organizational units (H_2, H_3). The organized process is seen as initiated by the generation of an innovative idea where idea generation is the result of a reasonably well-defined match of an organizational need or opportunity with a technological capability (H_4). The literature describes the information flow in terms of sources, participants, and content.

Three types of information flow are described. Corporate goals and policies, including budget availabilities, flow between top management and the innovative units (H_7, H_8, H_{9a}). Information related to technological capabilities flows to the innovative units from technological gatekeepers who monitor the relevant sciences and technologies (H_5). Market need information comes to the innovative units from external sources (H_6). The above inputs are all modified by such factors as individual mind sets, control/coordination implications of administrative policies, attitudes and actions of the immediate supervisor, and attitudes and actions of primary work and social groups (H_9).

Two basic process structures were identified. There is a phase-dominant one which structures the innovative activity by process phases within which nearly autonomous project effort is pursued. The other is project-dominant and it structures the innovative activity by projects within which all process phases are carried out. Certain information flows, and, hence, certain classes of innovation projects, are facilitated by a phase-dominant structure; whereas, other flows and projects are hindered. The same is true for a project-dominant structure. For example, a phase-dominant structure facilitates unimodular projects, but hinders multimodular projects (H_{10}); conversely, a project-dominant structure facilitates multimodular projects (H_{11}).

The administrative policies regarding control and coordination become manifest in terms of the complexity in the organizational incentive system, diversity in the organizational task structure, formalization in the definition of tasks, and centralization of power and decision making antonomy. These manifestations provide the means for expressing the focusing influence of administrative policy on individual behavior (H_{12}). Thus, they provide for a tie between administrative policy and organized technological innovation in a conceptual framework (H_{13}, H_{14}, H_{15}).

It is our conclusion that the literature is sufficiently advanced to support the development of conceptual frameworks. The logical operations of the framework, e.g., the mathematical algorithm, must be consistent with the information flow description of the process. The framework must permit the incorporation of the basic process structures and of the manifestations of the control and coordination policies and provide the capability to analyze their implications for organized innovation. Finally, the framework should yield insights consistent with the existing normative hypotheses which connect structure with type of innovation (H_{10}, H_{11}) and control and coordination processes with conditions in the external environment (H_{13}, H_{14}). Let us now turn our attention to presenting an illustrative comceptual framework and to supporting the second underlying premise.

III TOWARD A CONCEPTUAL FRAMEWORK AND AN ANALYTICAL METHODOLOGY

The second premise on which our current research is based is that the models and methodologies required for the analysis of a conceptual framework of goal formulation, idea generation, and resource flow relative to organized technological innovation can be developed. The purposes of this section are to present a preliminary framework and to illustrate the applicable models and methodologies.

As in the preceding section, it is not possible to review all the relevant methodological literature. Rather selected segments will be reviewed as necessary to accomplish the purposes of this section. Fortunately a number of recent state-of-art papers have appeared in the literature. Jennergren's 1974 paper (28), a preliminary version of a chapter for the "Handbook of Organizational Design", is an excellent summary and review of the literature dealing with decentralization in organizations. Of particular relevance is the material identified as "quantitative approaches" and "iterative decision mechanisms". A related summary and assessment concerned with mathematical models of coordination in decentralized organizations is provided by Freeland and Baker (29, 30). Baker also assessed the literature of resource allocation in organized R&D (31). The proposed model and the associated methodologies are drawn from these literatures.

A. Rosenbloom's Conceptual Framework

Rosenbloom (1) has proposed a conceptual framework which can function as a starting point for our development of a preliminary framework and of models and methods of analysis. He defines technological change as "the introduction to practice of new and more useful ways of serving human purposes" and an innovation as "the basic unit of technological change". As Rosenbloom notes, "the characteristics of all innovations are influenced not only by factors inherent in the innovation process, but also by what Merton has called 'the environing social and cultural structure'." (1, pg. 34).

The collection of forces outside the process of organized innovation which influence its behavior or outcome are referred to as its "context". Rosenbloom identifies and discusses one primary context in his manuscript (1, pp. 34-38):

1. structural context - the enduring pattern of social, economic, and political forces that impinge on the process in every situation and at several levels of aggregation including the immediate work group, the department, and the firm.

The structural context is then subdivided into two categories, namely:

2. organizational context - the "internal environment" which includes, among other factors, the organization's goals, formal structure, leadership, and resources.

3. environmental context - the "external environment" which includes, among other factors, technological trends, government policies, competitive behavior, and demand trends.

Rosenbloom credits the work of Bower (32) for the core of the idea just summarized. Bower analyzed what Rosenbloom refers to as the "organizational context". His observation of the presistent influence of organizational or structural forces on the technical, political, and economic acts of managers led Bower to the hypothesis that general managers could manipulate those forces to evoke desired behavior. His study supports the hypothesis, both with respect to resource allocation within firms and more generally, with respect to innovative behavior. Rosenbloom has enlarged Bower's viewpoint to include the contextual factors outside the firm.

Figure 3 is Rosenbloom's schematic of his conceptual framework of the process of organized innovation. Technological change is represented as a social process made up of three phases of tasks - idea generation, problem solving, and implementation. These tasks interact with their context, which Rosenbloom describes in terms of those forces within the organizational system performing the tasks of innovation and those external to the system.

The concept of corporate strategy is proposed as the basis for a higher level integrative frmework which can assist to clarify the relationship among the organizational and environmental factors. Rosenbloom accepts Andrew's definition of corporate strategy; namely, "Corporate strategy is the pattern of major objectives, purposes, or goals, and essential policies and plans for achieving those goals, stated in such a way as to define what business the company is in or is to be in and the kind of company it is or is to be." (33, pg. 28). Rosenbloom points out that the strategy framework integrates in two relevant dimensions (1, pp 37, 38);

1. it cuts across the boundary of the organization matching capability in the organizational context with opportunity in the external context - this matching was referred to as "idea generation" in the preceding section.

2. it cuts across organizational levels and boundaries as higher level strategic abstractions get translated into more concrete and implementable terms - this was referred to in terms of "the flow of corporate goals and policies from top management to the innovative units" and of "the manifestations of control and coordination".

"Research within the broad framework of corporate strategy could perhaps begin to clarify the apparent interactions among organizational goals, structure, and leadership as influences on technological innovation" (1, pg. 38). "The argument of this paper (Ronsebloom's) is that the concept of strategy offers a framework which can help us to design empirical studies which might generate 'explanations' of the process of technological change in firms and industries using only a few highly salient variables" (1, pg. 41).

Rosenbloom's conceptual framework is consistent with our analysis of the descriptive literature summarized in the preceding section. The descriptive literature adds detail to Rosenbloom's framework. For example, in addition to corporate strategy as a concept which cuts across the organizational and environmental contexts, the literature provides for information flow of technological and market-need capabilities. In addition to corporate strategy, the literature identifies individual mind sets, control/coordination mechanisms, attitudes and actions of the supervisor and the primary groups, and information input as mechanisms which focus the activities of the innovative units. The descriptive literature also provides alternative organizational structures

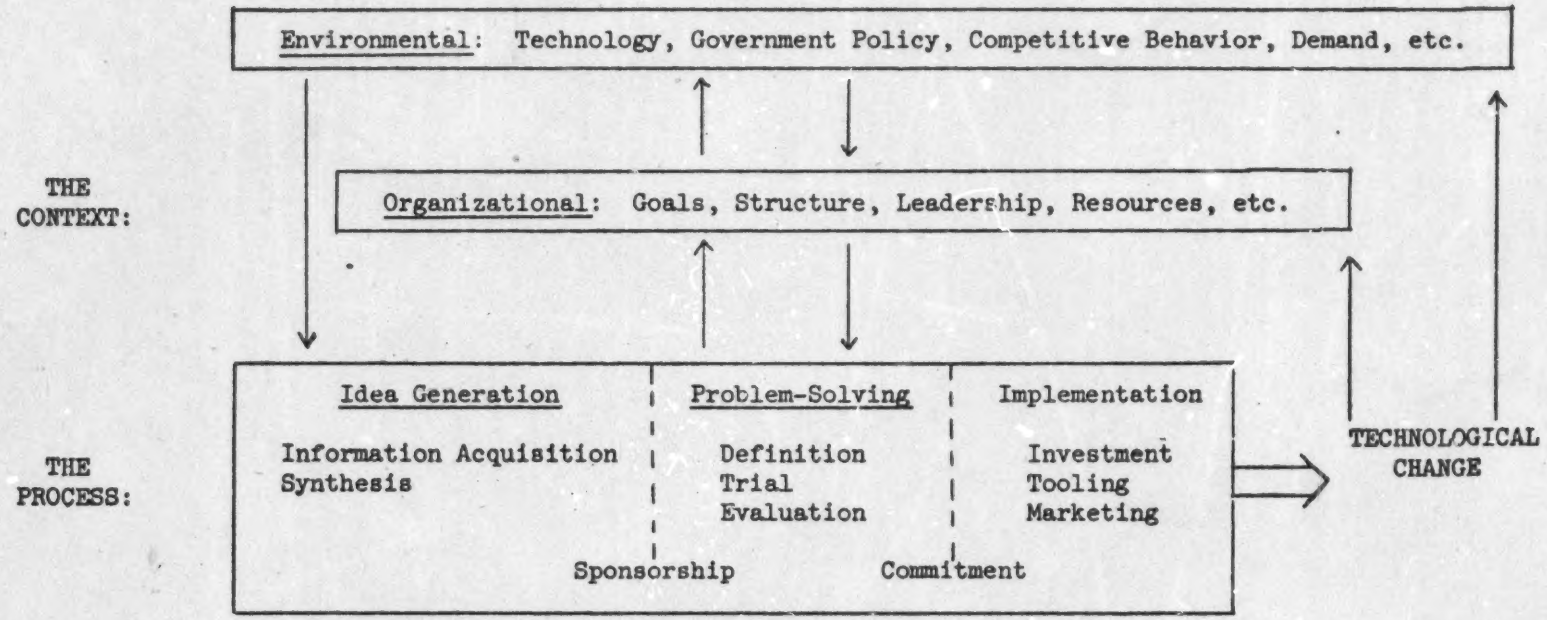


Figure 3: Rosenbloom's Conceptual Framework*

*From Rosenbloom (1, pg. 36).

(phase-dominant and process-dominant) and theoretical constructs (complexity, diversity, formalization, and centralization) which can assist in understanding the organizational context.

In summary, we are indebted to Rosenbloom for providing a conceptual framework and to the broader descriptive literature for the details relative to the process of organized innovation. We concur with Rosenbloom that a framework is necessary to help us design empirical studies which generate "explanations". We further believe that models and methods of anlaysis are necessary to facilitate the use of a framework as a design tool for empirical studies. Stated simply, one objective of this research is to integrate Rosenbloom's framework and the descriptive literature in the form of a mathematical model which can be subjected to logical analyses. The output of these analyses will help guide the formulation and conduct of future empirical studies and will provide explanative insights for managers and policy makers.

B. The Implementation of Corporate Strategy: Multi-year Planning and Fiscal Year Budgeting Processes

The driving force in the framework of organized technological innovation just presented is the process by which corporate strategy cuts across organizational levels and boundaries as higher level strategic abstractions get translated into more concrete and implementable terms at successively lower levels of the organization. This is not meant to downplay the other information flows and influencing factors which impinge on the process of organized innovation. They are important in that they provide for input from the environmental context and for focusing of the innovative activity. However, corporate strategy and the process by which it is implemented is the driving force which is impinged upon by the other factors.

Within the literature of mathematical models, the model form usually associated with corporate strategy, both with respect to the determinantion of corporate strategy and with its implementation across organizational levels and boundaries is called "resource allocation models", (28, pg. 65). The name "resource allocation" is somewhat a misnomer in that it tends to be more restrictive as a descriptor than are the models as descriptions. For example, such models can be used to represent the establishment of corporate goals and budgets subject to an overall organizational objective and resource availabilities. Or, they can represent the determination of funding levels for specific tasks subject to departmental goals and budgets (28, 29, 30, 34, 35).

The early resource allocation models were decision-event models. They implicitly assumed the existence of a decision maker who was, at some point in time, faced with the allocation of scarce resources to specified alternatives, such as budgets to organizational units, dollars to R&D projects, or manpower to specific research tasks. A very large body of literature resulted which included both models and methods of solution (e.g., see 28, 31, 36). The models were normative; i.e., they attempted to answer the question of how the resources should be allocated in order for the organization to achieve maximum benefit.

The decision events modeled in the early resource allocation models are inbedded within a more general process of multi-year planning and fiscal year budgeting. In large decentralized organizations, the process is hierarchical

and, despite simultaneous give and take, largely sequential in nature (e.g., see Figure 4). Each level in the organization receives guidance in the form of budgets and performance goals from higher levels and passes on guidance in the form of budgets and performance goals to the next lower level. In an analogous manner, information detailing how a proposal budget would be allocated to specific activities and the associated estimates of performance goal attainment flow upward in the organization with each level integrating the input from the lower levels.

Thus, resource allocation decisions get made at several organizational levels, and, at each level, an integration of proposed allocations by lower levels occurs subject to budget and goal guidance from higher levels. Baker, et al (37) and Shumway, et al (38) describe such a process for one large federal agency. Figure 4 is a schematic of that particular process. The process takes place annually, but it is important to understand that both multi-year planning and fiscal year budgeting are being accomplished and that the process may iterate several times. The planning and budgeting process just described is one common means by which corporate strategy is translated into more concrete and implementable terms, especially with respect to organized innovation (35).

An alternative, but consistent, view of the process is offered by Connolly (39). He argues that for several reasons - the lack of an identifiable decision maker, an extended time frame, and the importance of coordination mechanisms - the planning and budgeting of expenditures for organized innovation within a large organization is not conveniently modeled as a decision event, but must be modeled as a decision process. Further, the process is diffuse in nature: i.e., the processes are temporally diffuse, covering extended periods of time, with indistinct endpoints; and multi-person with decision making influence and responsibilities diffused across a number of individuals; are geographically diffuse in that individuals are separated by non-trivial distances; and are diffused across several organizational levels.

The early resource allocation models were decision-event models. They focused on the problem as viewed at a specific organizational level at a specific point in time. These models assume as known both 1) the guidance, budget and/or performance goals, which was communicated from above and 2) the alternatives, innovation projects, which were recommended from below and were competing for the scarce resources. They did not model the process; there was no inherent mechanism for modifying guidance or for redesigning existing alternatives or generating new alternatives. The question addressed was how to allocate resources to known alternatives in order to maximize some objective and achieve at least acceptable performance goals (28, 31, 35).

That such decision-event models have satisfied some normative needs within the organization should not be denied. Especially in their interactive forms (37, 40, 41), these models operate in an "information" mode, rather than a "decision" mode, and offer considerable assistance to the decision maker relative to the decision he faces at his level in the organizational hierarchy.

There is some data to confirm that the decision-event, resource allocation models can be fine-tuned to predict the decisions of an individual decision maker. Table 3 contains data which were collected within a large, decentralized R&D organization within a federal agency (37). The product moment correlation

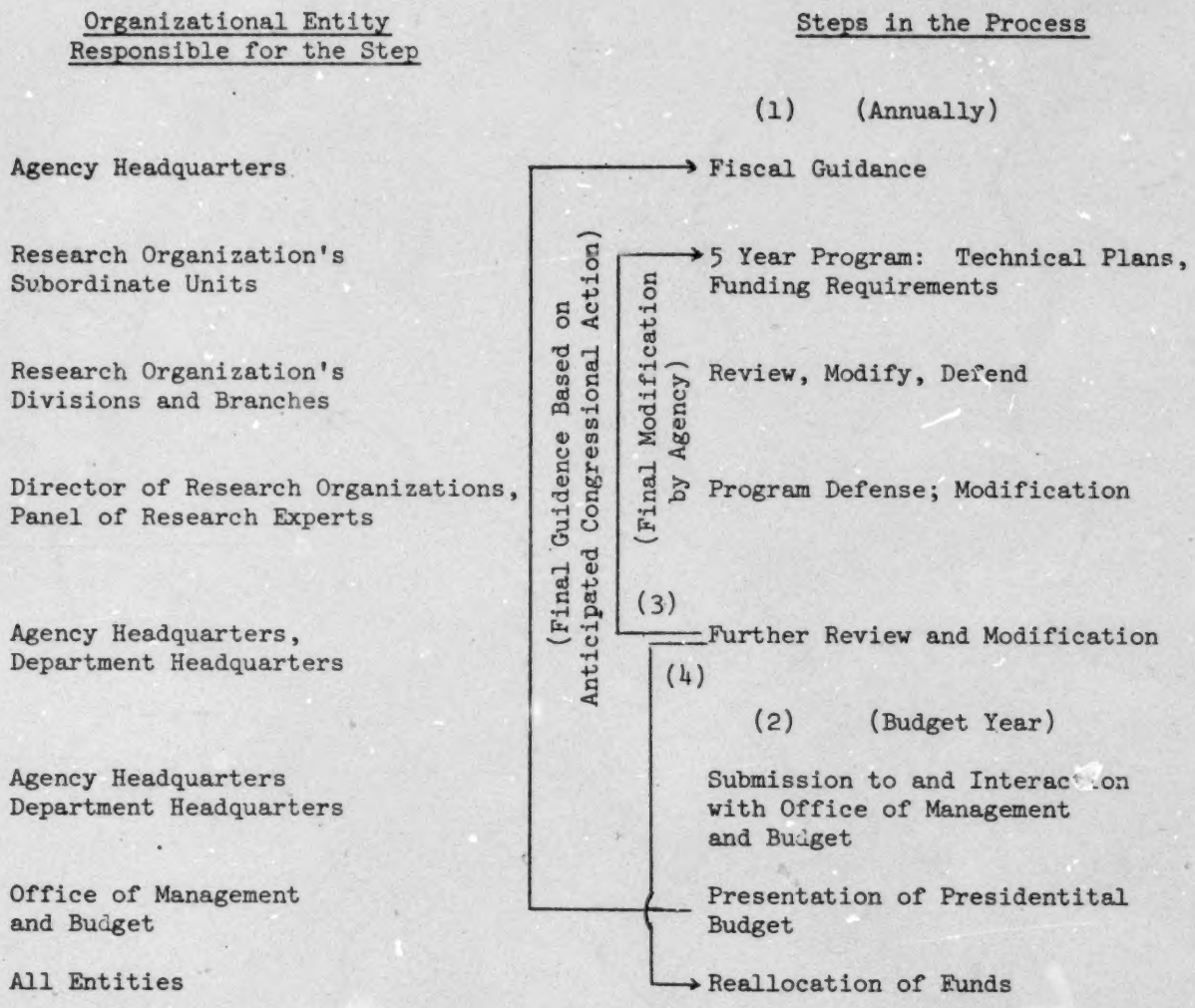

Organizational Entity Responsible for the Step
Steps in the Process
(1) (Annually)
Agency Headquarters
Fiscal Guidance
Research Organization's Subordinate Units
5 Year Program: Technical Plans, Funding Requirements
Research Organization's Divisions and Branches
Review, Modify, Defend
Director of Research Organizations, Panel of Research Experts
Program Defense; Modification
(Final Guidence Based on Anticipated Congressional Action)
(Final Modification by Agency)
(3)
Agency Headquarters, Department Headquarters
Further Review and Modification
(4)
(2) (Budget Year)
Agency Headquarters Department Headquarters
Submission to and Interaction with Office of Management and Budget
Office of Management and Budget
Presentation of Presidentital Budget
All Entities
Reallocation of Funds

Figure 4: Schematic of the Budget Process*

*From Shumway, et al, (38).

Form of Benefit Function	Branch Number of Alternatives	Correlations at Base Funding		Correlations at Decrement	
		Pearson Product Moment	Spearman Rank	Product Moment	Spearman Rank
Simple Comparative	A: 12 projects	.7016**	.7228*	.8785*	.8952*
	A[1]: 12 projects	.9355*	.9158*	.9419*	.9383*
	B: 5 projects	.8839**	.8000	.9750**	.9747**
	B: 27 tasks	.6055*	.5989*	.7020*	.6142*
	C: 7 porjects	.9624*	.9370*	.9911*	.9370*
	C: 25 tasks	.9903*	.9798*	(2)	(2)
	D: 11 projects	.5791**	.8909*	.8068**	.9000*
	D: 27 tasks	.7067*	.793*	.8252*	.8342*
Scoring Models	A: 12 projects	.7155**	.7579**	(2)	(2)
	A[1]: 9 projects	.9639*	1.000*	.9891*	.9828*
	B: 5 projects	.6549	.7000	.2800	.3591

1. Branch Chief A requested that his benefit scores be divided by cost thus yielding a benefit/cost which was then maximized subject to budget (cost) constraints. The correlations associated with A^1 are based on this cost-adjustment. The implications of this adjestment are analyzed in detail.

2. The data are not available for these correlations.

* significant at .001.

** significant at .05.

Table 3: Correlations of Model Output with Actual Budget Recommendations***

*** From Baker, et al, (37)

The decision makers were required to make budget recommendations for two guidance inputs: one referred to as base and the other as derement (20% less than base).

measures the relationship between the level of funding actually recommended by the decision maker and that level suggested by the model, alternative by alternative. In order to compute the rank correlation, the alternatives were rank ordered according to the level of funding and these ranks were then correlated. Thus, if both correlations are high, the level of funding of each alternative and the relative rank position of the funding level of each alternative are similar in the two budget allocations. At the time the decision makers finalized their recommendations, they did not know the model output. There are strong similarities between model output and actual recommendations, thus supporting the hypothesis that the models had significant predictive validity. Accordingly, we propose to use the decision-event models to represent the resource allocation decisions which are made at each organizational level.

C. Iterative Decision Mechanisms

In recent years, the decision-event models have been extended to be more like the multi-year planning and fiscal year budget processes of interest in this proposal. These process models emphasize the hierarchical and sequential aspects of the process and call for an iterative exchange of information between organizational levels and units (for example, 28, 29, 30, 34, 35). Jennergren refers to these models and methodologies as "iterative decision mechanisms" (28, pg. 68). They are also referred to in the literature as "multilevel planning processes" (42, pp. 70-71). We propose to adopt and modify the models and methodologies of the "iterative decision mechanisms" literature as our representation of the process by which the goals and budgets determined by the decision-event models are communicated and modified.

As Jennergren (28) and Freeland and Baker (29) have pointed out, there are a number of iterative decision mechanisms which have been proposed. The mechanisms were developed for different purposes and each has distinct properties which render it more or less desirable for any specific application. It is beyond the scope of our current needs to attempt to discuss each mechanism or even to summarize the various classes. The previously mentioned manscripts (28, 29) have already done this. Instead, one specific iterative decision mechanism will be described. It was selected because of its apparent consistency with Rosenbloom's conceptual framework and with the description of the multi-year planning and fiscal year budgeting process and because it appears to offer the flexibility necessary for incorporating the salient issues of the working hypotheses drawn from the innovation literature.

The basic structure of the iterative decision mechanism selected for presentation originated with Ruefli and his concern with modeling planning and resource allocation in decentralized organizations (34, 35). Ruefli proposes the generalized simplex method as the decision mechanism. However, Freeland points out that this mechanism has some unfortunate consequences from the point of view of interpretations regarding organizational behavior (30; 44, pp. 142-194). A primal decomposition method was proposed which overcame these consequences. Both Ruefli and Freeland model a process within the organization which explicitly considers the interaction between superordinates and subordinates and is concerned with goal formulation and budget allocation and the opportunity for alternative (or project) redesign.

Rzasa (43) extended the Ruefli-Freland structure to include the explicit consideration of a client or customer. It is the Rzasa formulation which we

propose as a starting point for constructing models and methodologies related to the process or organized innovation. Rather than to go through all of the mathematical details, which are available in the dissertation (43), we will discuss Figure 5, "Schematic of an Iterative Decision Mechanism", which identifies the components of the mathematical model and illustrates the interactive information flows inherent to the model.

D. An Illustrative Iterative Decision Mechanism

The iterative decision mechanism described in this section and summarized in Figure 5 can be viewed as a model of a multi-year planning and fiscal year budgeting process. As such it has much in common with the processes described in Section III. B and summarized in Figure 4. The reader is encouraged to keep the content of Section III. B in mind as he/she reads this section.

The internal organizational process has three major elements. First, top corporate management (superordinate level) considers the exogenous inputs and determines corporate strategy in terms of performance goals and budget for each subordinate division. These goals and budgets are then communicated to the appropriate subordinate organizational units. Although not shown in Figure 5, for the sake of simplicity, goal and budget formulation can be repeated successively for as many organizational levels as desired. For example, divisional management may send more specific goals and budgets to departmental management who in turn may send more highly specified goals and budgets to group leaders. The mathematical formulation is sufficiently general that any reasonable number of organizational levels and any reasonable number of organizational units at a given level can be accomodated. Thus, the area of Figure 5 denoted by "subordinates" is much more complex than indicated: in the mathematical model for the simulation capability it will represent the organizational structure (e.g., either a "phase-dominant" or a "project-dominant" structure could be represented).

Regardless of specific structure, the subordinate units send proposed resource allocations (plans) back to corporate management. For example, the subordinate might send back a list of proposed innovation activities and recommended budgets.* The corporate management evaluates these plans relative to overall corporate objectives. If the plans are not satisfactory, new goals and budgets are determined and communicated. The process iterates until top corporate management decides that a satisfactory plan has been proposed by the subordinates.

The plan is then checked with respect to the organization's perception of customer (or client) needs and wants. If not satisfactory, this dissatisfaction is conveyed to the subordinate units. The subordinate unit then attempts technological redesign of existing alternatives and the generation of new alternatives (idea generation). If redesign of new alternatives are possible, then a modified plan is established. Both the goal and budget process and the redesign process are repeated until a satisfactory plan is determined or until no further improvement is possible.

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*The model form suggested by Ruefli (34), Freeland (44), and Rzasa (43) for the subordinate decison problem is structurally equivalent to the model used by Baker, et al (37). Thus, the empirical results of Table 3 are applicable and provide some evidence for the descriptive validity of the model used for the subordinate decision problem.

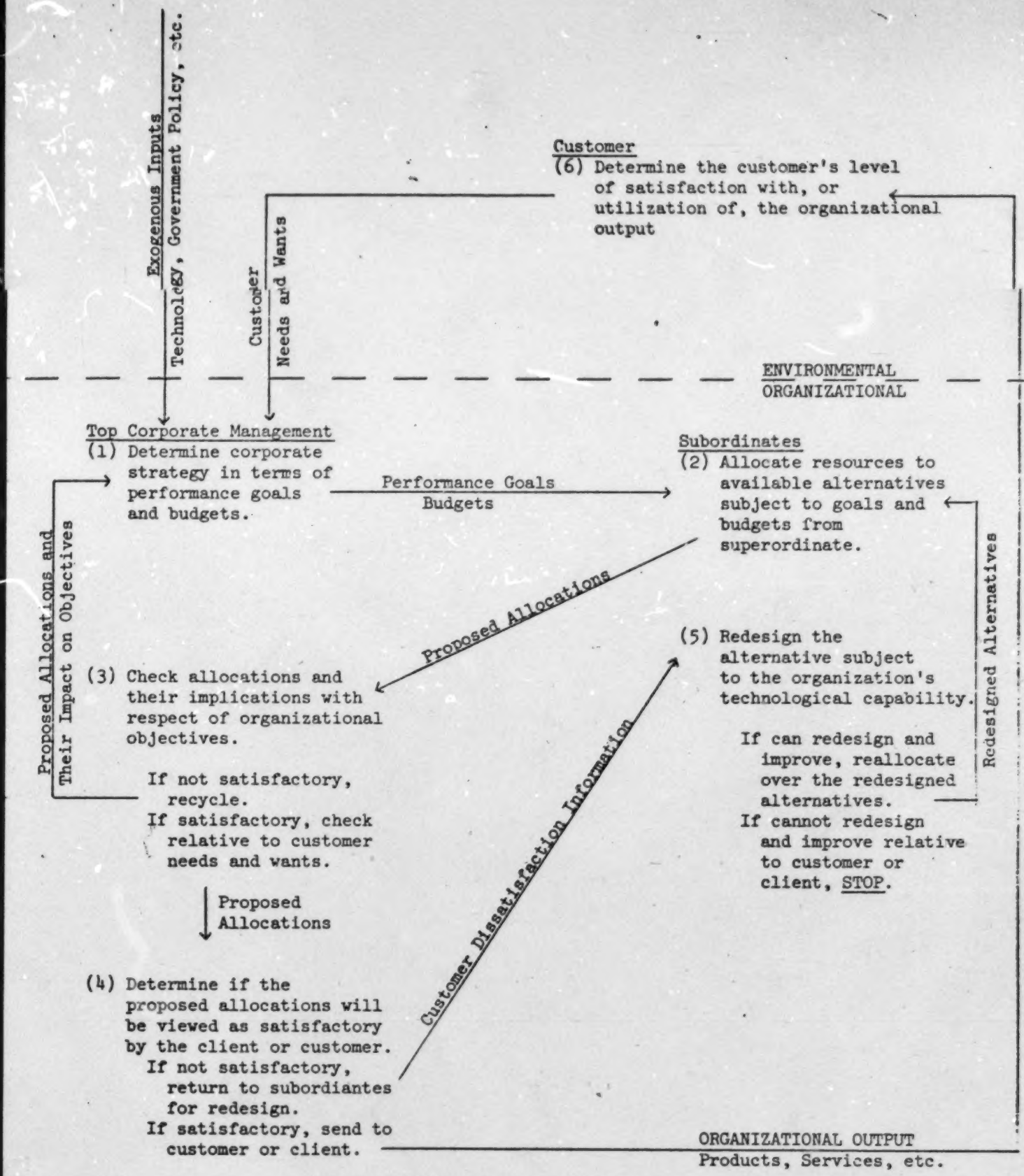
Exogenous Inputs
Technology, Government Policy, etc.
Customer
Needs and Wants
Customer
(6) Determine the customer's level of satisfaction with, or utilization of, the organizational output
ENVIRONMENTAL
ORGANIZATIONAL
Top Corporate Management
(1) Determine corporate strategy in terms of performance goals and budgets.
Performance Goals
Budgets
Subordinates
(2) Allocate resources to available alternatives subject to goals and budgets from superordinate.
Proposed Allocations and Their Impact on Objectives
Proposed Allocations
(3) Check allocations and their implications with respect of organizational objectives.
If not satisfactory, recycle.
If satisfactory, check relative to customer needs and wants.
Proposed Allocations
(4) Determine if the proposed allocations will be viewed as satisfactory by the client or customer.
If not satisfactory, return to subordiantes for redesign.
If satisfactory, send to customer or client.
Customer Dissatisfaction Information
(5) Redesign the alternative subject to the organization's technological capability.
If can redesign and improve, reallocate over the redesigned alternatives.
If cannot redesign and improve relative to customer or client, STOP.
Redesigned Alternatives
ORGANIZATIONAL OUTPUT
Products, Services, etc.

Figure 5: Schematic of an Iterative Decision Mechanism*

*Adopted from Rzasa (43).

When a plan has been deemed "satisfacoty" with respect to both organizational goals and customer needs. The existing iterative decision mechanism treats the projected results of the plan as if it were organizational output. As now formulated it does not explicitly consider the implementation aspects of the innovation activity and does not recognize deviation from the plan. It does explicitly consider feedback from the customer or client in the form of satisfactions, or dissatisfactions, and of needs and wants. Such feedback is the initiating signal for a recycling of the process.

The iterative decision mechanism just discussed appears to capture most of the corporate strategy aspects of Rosenbloom's conceptual framework and to be consistent with the existing descriptions of planning and budgeting for organized technological innovation. (28, 35, 38, 39, and Section III, B). The mechanism is more general and inclusive than is apparent from this summary presentation. As mentioned, the so-called "subordinates" sector of the model can be formulated so as to represent any of a number of structures for organized technological innovation; most importantly, it can be formulated to represent either a "phase-dominent" or a "project-dominant" structure. Further, certain of the "organizational decision rules" could be modified; for example, the definition of "satisfactory" can be changed and the implications examined. Further, the subprocesses now iterate until a plan is judged "satisfactory"; instead the process could permit a fixed number of iterations, say 5, and then continue to the next phase. Thus, a number of modifications can be presented for the planning and budgeting process and the ramifications with the respect of organized technological innovation can be examined for a number of organizational structures.

It is clear that the above modifications can be made to the iterative decision mechanism. There are other changes which we think can be included, but which would require some effort to accomplish. It appears that the theoretical constructs related to complexity in the organizational incentive system, diversity in the organizational task structure, formalization in the definition of tasks, and centralization of power and decision making autonomy can be built in. It should be possible to permit exogenous input at the subordinate level; e.g., technological and customer information. It is not clear which of the other focusing mechanisms can be included, but this should be investigated. The iterative decision mechanism is more general than appears from first introduction; exactly how general and precisely what can be included must be determined as part of the project effort.

E. An Analytical Methodology

The iterative decision mechanism of the preceding section can be modified and extended to model the corporate strategy process and can function as the driving force for a simulation model of goal formulation, idea generation, and resource flow relative to organized technological innovation. Some of the influencing factors can also be included in the mechanism. However, the iterative decision mechanism is not sufficient for two reasons. First, although the decision mechanism provides a logic structure, it does not, per se, provide an analytical methodology. Second, important influencing factors are not included.

To be sufficient, an analytical metnodology must provide the capability of examining the ramifications of organizational structure, corporate strategy, focusing mechanisms, and exogenous inputs on goal formulation, idea generation, and resource flow relative to organized technological innovation. These

ramifications must be studied over time. To accomplish this, we propose the construction of a computer simulation capability. The underlying model will include an iterative decision mechanism as the driving force and supplemental considerations, as necessary to include important influencing factors.* Figure 6 is a schematic representation of an illustrative simulation model.

The supplemental considerations identified in Figure 6 include:

1. the implementation phase of the organized innovation process.

2. the focusing mechanisms not explicitly included in the iterative decision mechanism.

3. gatekeepers, both technological and market-need, which function as an information linkage connecting the environmental and organizational contexts.

4. exogenous input in the form of governmental policy and market structure.

For the initial simulation capability, each of these must be given as a boundary condition. Subsequent research could lead to the design of specific subsystems for all, or selected, influencing factors.

Note that the result will be an analytical methodology at the level of the firm. It should be possible to extend the capability to a multi-firm analysis. Such an extension is not proposed herein. Instead, we propose to construct a single firm capability and to demonstrate its utility for guiding future empirical studies and for assisting in policy and managerial analyses. Following that, if desirable, a multi-firm capability could be developed.

F. Summary and Conclusion

Rosenbloom's conceptual scheme has been described and his conjecture that corporate strategy is a useful integrating focus has been accepted. In order to specify the process by which corporate strategy impinges on organized technological innovation, the descriptive literature of multi-year planning and fiscal year budgeting was examined. As a result, a description of goal setting and budgeting within large, decentralized organizations was proposed.

The evolution of the "resource allocation models" literature as applied to corporate strategy was traced. It was shown that the literature grew from an emphasis on decision-events, and decision-event models, to an emphasis on decision processes, and iterative decision mechanisms. Rzasa"s iterative

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*We are aware of one other simulation model which uses an iterative decision mechanism as a driving force (45). In this study by Jennergren and Müller, a large number of quadratic production - planning problems were generated. They were solved by means of two iterative mechanisms, a method based on the Dantzig-Wolfe algorithm and a price-adjustment method. The number of iterations of information exchange between corporate headquarters and divisions was low in all cases (betwwen 2 and 5) and the Dantzig-Wolfe method generally produced "good" solutions.

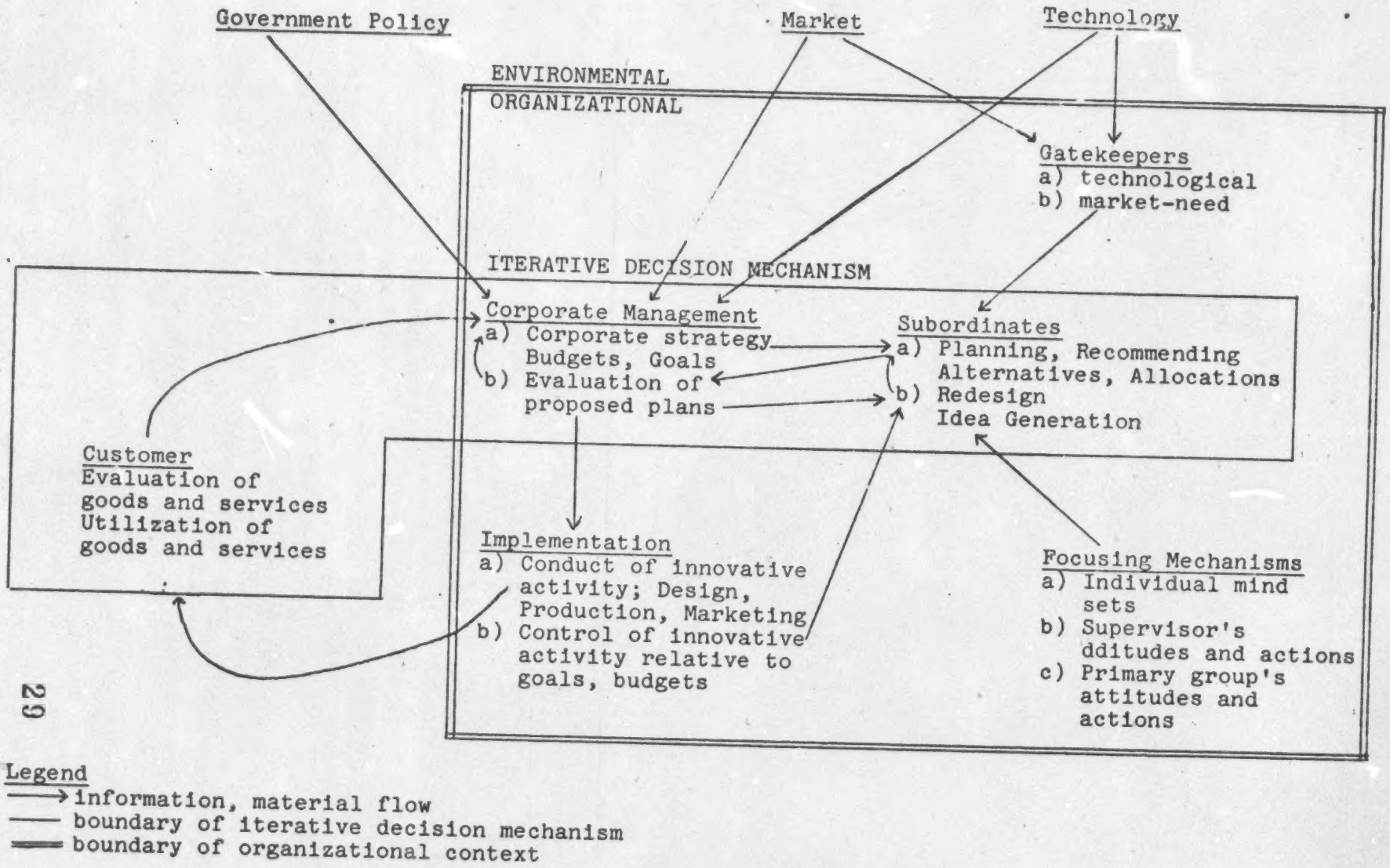

Figure 6: Schematic of Illustrative Simulation Model

decision mechanism was described and an argument was given that this mechanism could be modified and extended to capture the corporate strategy oreintation proposed by Rosenbloom and to be consistent with the existing description of planning and budgeting for organized technological innovation.

It was proposed that the modified and extended iterative decision mechanism be used as the driving force for a computer simulation capability. The simulation model would also include consideration of the implementation phase, focusing mechanisms, gatekeepers, and exogenous input regarding governmental policies, market characteristics, and technological information. An illustrative simulation model was presented and discussed.

Our second basic premise was that the models and methodologies required for the analysis of a conceptual framework of goal formulation, idea generation and resource flow relative to organized technological innovation can be developed. It is our conclusion that this premise is correct.

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